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Experiment Station**

General Technical
Report PSW-52

Returns on Investments in Management Sciences: six case studies

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Ernst S. Valfer **Malcolm W. Kirby** **Gideon Schwarzbart**

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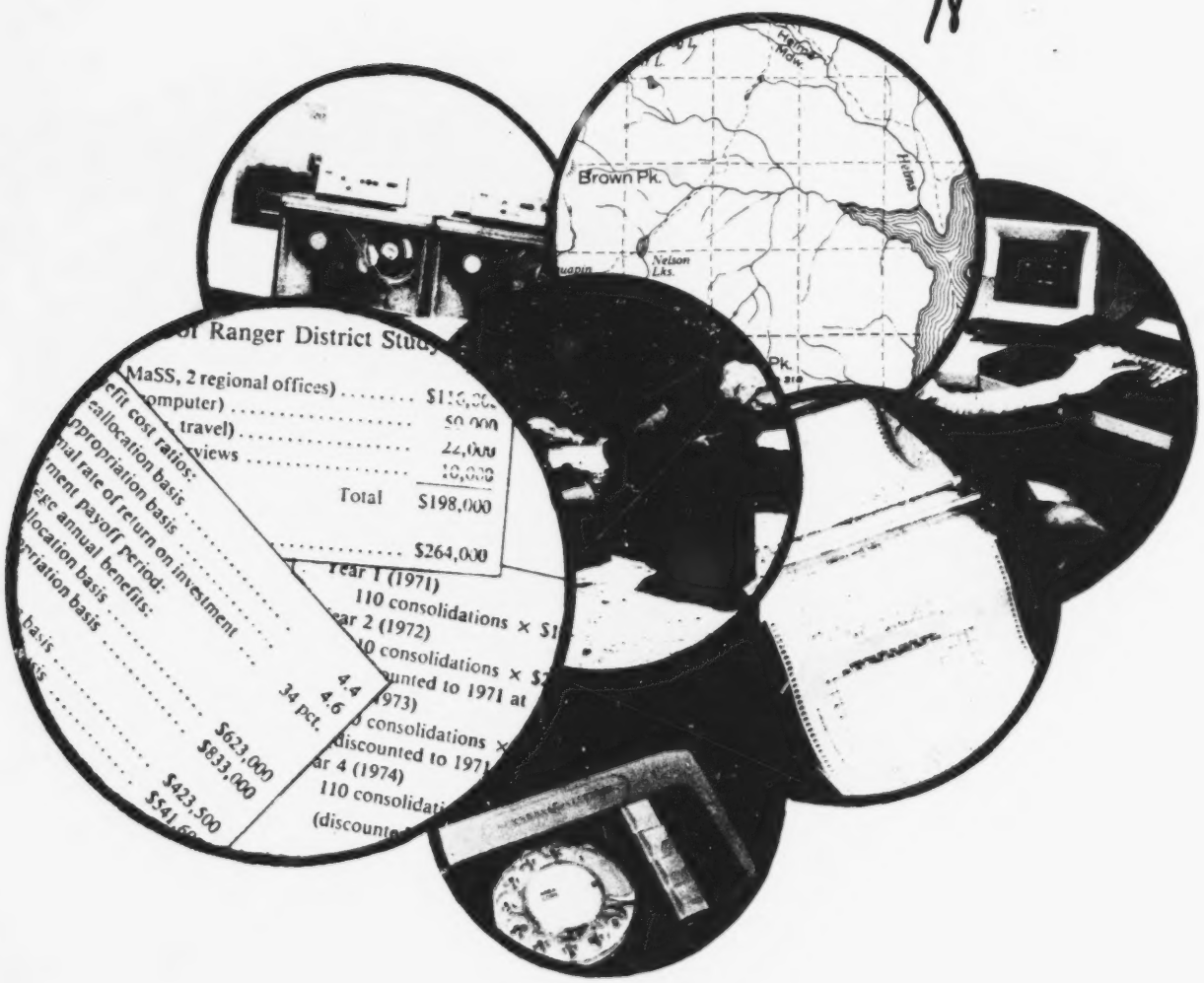

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The Management Sciences Staff (MaSS) is the internal consultant to the Forest Service, U.S. Department of Agriculture in the management sciences. It makes studies and advises agency management in decisionmaking and problem resolution. The interdisciplinary staff, established in late 1962, is located at the Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

From 1962 through 1979, the Staff conducted 41 major studies, participated in 29 large-scale studies led by other Forest Service staff or line officers, and provided numerous consultations. More than 100 publications and staff papers have resulted from this effort. Programs of work and studies recommended by the Staff have been generally well received by Forest Service management, and implementation of recommendations was unusually high.

Now, 19 years after its inception, an appraisal of the Management Sciences Staff by its own members seems warranted and appropriate. Such an effort, however limited, might help demonstrate to management how well it utilizes MaSS, and to staff members their skill and expertise in identifying research studies of potentially high merit to the agency.

The studies analyzed in this report were conducted over the last 14 years. It was often extremely difficult to obtain reliable figures for either the costs incurred or the benefits accrued, particularly for the earlier studies. A cost-benefit evaluation of a major study is in itself a major effort. Staff time was neither budgeted nor available for making comprehensive economic analyses of past studies. Economic analyses of a small sample of past studies seemed more feasible. The sample size was arbitrarily set at six to include the five highest investment studies, and one past study on transportation—a major current MaSS research topic.

To ensure objectivity, such evaluations should be made by third parties so that neither the consultant nor the client are tempted to interpret data with bias. To this end, we asked third parties to generate and review the benefit data. The MaSS analyst neither compiled nor determined the benefits or losses for each study. Cost data, however, were collected and evaluated primarily by MaSS analysts. The cost data tended to be more readily available and were less subject to debate.

No attempt is made here to be exhaustive. Each study is described briefly to provide the background essential to understanding the purposes and consequences of these studies. The methodology used to arrive at a solution —data collection, analytical procedures, models or other means to determine recommended management decisions— is not described. Also not included are the social factors which either hindered or hastened the acceptance of the recommendations and how the Staff dealt with such factors. The references list the full reports of these studies.

The qualitative and quantitative cost-benefit data are presented only in summary. The original quantitative benefit data remain with the third-party analysts. We were provided with a first summation which was further condensed for these reports. We did not have the means to verify the summaries against the original data sources. But based on the diligence and competence of the third-party analysts, it is assumed that their data reflect the actual situation with sufficient precision. Study cost data, however, were compiled in-house on the basis of known time and operating costs incurred by the staff and direct collaborators, and estimates of the time and other contributions of second- and third-party participants. The study implementation costs were also compiled by the third-party analysts as part of the benefit analysis.

Our economic calculations were made by using generally accepted standards for such investment evaluations. All investments and benefits have been discounted at an interest rate of 10 percent as specified in the U.S. Office of Management and Budget (OMB) Circular A-94 (revised). The calculations were made in conformity with generally accepted engineering economics principles and reflect as fairly as possible the qualitative and quantitative consequences of the investment.

SUCCESS RATES

The six analyzed studies, fortunately, were all successful. Recommendations were totally or largely accepted and implemented. Furthermore, all of the studies in this report were highly beneficial in terms of commonly measured investment ratios though such was not necessarily expected. The calculated internal rate of return on investment ranged from 34 percent to 184 percent for five of the six studies (the evaluation of the sixth study was only qualitative). Internal rates of return of the order of 50 percent or above are often cited by economists as clear evidence of underinvestment (Evenson and others 1979).

These six studies were not selected on the basis of predetermined outcome. In fact, two of them were expected to have only marginal benefits. A breakdown of the 41 major studies made from 1962 to 1979 shows:

- Recommendations accepted or fully implemented—12 studies
- Recommendations partially accepted or partially implemented—7 studies
- Findings used in other ways such as input into other studies—7 studies
- Findings not used—1 study
- Ongoing—14 studies.

Only the Fire Overhead Manpower Evaluation Scheme, completed in 1976, has never been operationally applied. It has, however, been used as a training device in fire management courses. This record attests to the sensitivity and acuteness of management in isolating significant problems which should be assigned to the Management Sciences Staff in order to obtain a sufficient rate of return on investments with high probability. The Staff, in turn, seems reasonably able to predict those assignments which will provide a fair return to the organization.

The success rate for major consultations or contributions to studies by others is even more difficult to document. A consultant is called in for short periods and provides specific counsel, but is not necessarily party to the total problem analysis or to the final deliberations or evaluations by the consultee.

Requests for any of the references listed in this report should be directed to:

Management Sciences Staff
Pacific Southwest Forest and Range Experiment Station
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SIX CASE STUDIES

Size of Ranger District

The Size of Ranger District Study completed in 1968 was the first large MaSS study. The recommendations from that study included the proviso that before any districts were combined or split, the Administrative Management Staff of the Forest Service Region concerned would have to study in detail the costs and benefits resulting from this particular organizational modification. Unfortunately, the results of these regional analyses were never centrally compiled and made available. In 1978, when the request was made for benefit and cost data relating to these district size changes, only data from 1973 through 1976 were readily available. The analyses, therefore, had to be extrapolated from data from this period. The extrapolation was made under reasonably narrow assumptions as explained in the analysis.

The unusually high rate of return for this study is a reflection of the considerable savings achieved at most districts, with very small local investment to attain these changes. The study cost was modest in comparison to the broad application.

The Size of Ranger District Study served as the model for a subsequent Size of Forest Study, conducted in 1970-71 by the Division of Administrative Management, Forest Service, U.S. Department of Agriculture, Washington, D.C. The findings from this study were also successfully and beneficially implemented.

Solid Waste Management

The Solid Waste Management Study was completed in 1971. The recommended decision model was adopted and implemented in the Rocky Mountain Region and in many Forests in other Regions. The benefits had to be synthesized by comparing (a) the costs of solid waste disposal if the recommended model was used, with (b) the costs of alternative solid waste disposal practices over the same period because no such data were available at the Forests. The study investments were depreciated over a 3-year period (1972-74).

The prescriptions of the model have become standard practices in many Forests. Savings continue to accrue beyond the 3-year amortization period. Another benefit excluded from this evaluation is the lower equipment investments resulting from the reduced travel mileage generated by this model.

Forest Service Telecommunications

The Service-Wide Telecommunications Study was completed in 1972, and implementation of recommendations will continue over the next several years. Some of these recommendations involve complex technology and large investments in new equipment. The highest rates of return are expected from the ongoing implementations of the recommended new technology for fire and air communication systems. Estimates of these potential benefits, however, are too tenuous to be included in this evaluation. Therefore, this economic analysis is based solely on benefits already obtained against which the whole cost of the study has been amortized. Had study costs been broken into segments related to various benefits, the return on investment would have been much higher.

Analysis of Computer Support Systems for Multifunctional Planning

This analysis of computer systems resulted in three relatively independent reports—two completed in 1974, the third in 1976. The findings were used widely, and many of the recommendations were adopted. Subsequently, other task forces focused on some problem areas addressed by this study. The impact of management actions taken as a result of these analyses was most significant.

No detailed economic evaluation was made because the known benefits from management action cannot be separated into those resulting from this study or from later analyses. The Computer Support Systems Analysis was one of our largest studies and is, therefore, included in this report.

ADVENT

ADVENT is a large computer software package and system. It permits comparative analyses of large scale programs and budgets and the generation of alternatives on a consistent agency-wide basis at all organizational levels. The precursor of ADVENT was the Eldorado Program Planning and Budgeting System, which was developed during the mid 1960's, but later shelved. The need for a large scale, yet flexible, program planning tool resurfaced in the 1970's, resulting in the development of ADVENT. National implementation of ADVENT began in 1975 and was completed in 1980.

ADVENT was modified in 1978 to generate the Forest and Rangeland Renewable Resources Planning Act (RPA) program for fiscal year 1980. The Staff provides user assistance for ADVENT and made minor modifications for more efficient adaptations. The investment costs to design and implement ADVENT are reasonably well known. The benefits deriving from its use are less well documented. We used third party estimates to determine benefits accruing to the user of ADVENT derived from program development and budgeting. Several independent third party estimates were available, the most conservative of which was used in this analysis. Estimates of the benefits resulting from ADVENT in the RPA application had to be obtained from the users.

Rock Aggregates Transport

In contrast to the other studies, the Rock Aggregates Transport analysis deals with a relatively modest MaSS effort. This study is included because it is typical of a series of low investment studies which led Staff members to explore land transportation problems. The largest ongoing MaSS study is now devoted to such problems.

The study, completed in 1976, was designed for application on up to 20 National Forests with the most severe road maintenance problems. The only reliable benefit data obtainable came from a single National Forest. The benefits reported from that single application served to amortize the total cost of the study and to calculate the rates of return. For any additional applications, the marginal cost will be considerably lower than for the one forest.

SIZE OF RANGER DISTRICT

Benefit-Cost Analysis

The Size of Ranger District Study was conducted in 1967-1968 for the Forest Service's Division of Administrative Management. The Management Sciences Staff was augmented by one senior National Forest System (NFS) line officer who headed the team and one midlevel NFS staff officer. MaSS assumed technical responsibility for developing the study procedures and methodology and for data analysis and evaluation.

The study was requested by the Chief of the Forest Service because of uncertainty about the structure of ranger districts and its ability to respond to future program and budget changes. Two opposing theories predominated within the agency hierarchy. The Chief and other senior officers envisioned small, intimate districts as having the highest level of operating efficiency. Adherents of the opposing viewpoint suggested that districts needed to be enlarged to effectively accommodate new programs and directions. The Deckard Committee[1] had recommended in 1966 the need to review the then existing policy of district size.

The specific objectives of the MaSS study were:

- Determine whether a relationship exists between the size and effectiveness of a ranger district
- Develop criteria to determine the acceptable range in the size of districts to carry out Forest Service program objectives effectively and economically
- Establish procedures to evaluate each district or combination of districts for desirability of size change.

A size-effectiveness relationship was established and the second and third objectives were satisfied by the study. The study recommendations on size and staffing of ranger districts contradicted existing size policy. The recommendations were supported by eight of the nine Regional Foresters and were finally accepted by the Chief. Implementation of the recommendations began in 1968.

The report recommended relatively rigorous guidelines for selecting and ranking districts to be examined for potential consolidation and future reapportionment. No district consolidation was authorized until the Regional Office provided a detailed analysis of the social and economic consequences stemming from the proposal. When negative consequences outweighed the gains, the proposal was discarded by the Regional or Washington Office.

Benefits

Recommendations were made and implemented which produced improvements in the following areas:

- Resource management—By consolidating the smaller districts, a wider range of skills were made affordable and available to the restructured districts.
- Service to the public—The higher skill level resulted in more complete and authoritative service to the public. In some instances, consolidation made the nearest district office less accessible to the public, offsetting to some degree the skill benefits, although such effects were negligible overall.
- Organizational management—The availability of skilled staff assistance facilitated significantly the ability of District Rangers to manage their organizational units. The suggested upper limit in district growth safeguarded districts from becoming too unwieldy for effective management.

Economic Benefits

Projections

Operating costs were predicted to be modified by salaries due to shifts in the number and grades of employees, travel due to transfer of some headquarter locations, and rents and utilities at headquarters.

The study estimated that 455 of the then existing 822 districts could be combined, resulting in a probable annual savings exceeding $2,000 (1968 dollars) for each combination. Of these potential 455 combinations, 153 were predicted to yield probable annual savings exceeding $10,000. These 153 districts were thus assumed to be the most likely candidates for consolidation on economic grounds.

Results

As a result of implementing the proposed district-size policy, 161 districts were eliminated between the years 1967 and 1978. Those consolidations which were operationally and politically easiest to achieve and which were expected to yield the highest economic return were naturally given priority.

Each district consolidation was preceded by a regional cost-benefit analysis. These data had to be submitted to the Chief's Office. This cost-benefit evaluation of the Size of Ranger District Study used these regional data as compiled by the Forest Service's Washington Office. Unfortunately, documented costs and savings data for con-

[1]Edwin Deckard and others. "Review of Management Practices and Manpower Utilization in the Forest Service." Joint Management Improvement and Manpower Review Team. Washington, D.C. July 1966.

solidations before 1973 were no longer readily available in 1979 when this analysis was made. The available data related to only 22 district consolidations in six Forest Service Regions (Northern, Southwestern, Intermountain, Pacific Southwest, Southern, Eastern) during the period 1973 to 1976. In two cases, three districts were consolidated into one.

The Oconee National Forest provided a consolidation analysis with a once-only cost figure, but no savings data. Therefore, no savings were assumed for this consolidation. The analyses of six other consolidations showed neither marked cost nor benefit figures.

Three of these 22 analyses identified major once-only setup costs for moving or other adjustments, averaging $10,000 per consolidation.

Organizational consolidations without some once-only costs are highly unlikely, even if the consolidations took place within the same building. For most of the districts where a separate once-only cost is not shown, the indicated savings probably are the first year net savings. The breakdown of available data does not, however, allow this assumption to be tested. The more restrictive assumption must therefore be made that all consolidations incurred an average once-only cost of $10,000.

Annual savings reported for 15 district consolidations ranged from $3,677, at the Uinta National Forest, to $84,000, for a three-district consolidation at the Apache-Sitgreaves National Forest. The combined annual savings for these 15 districts is $324,820 or $21,655 per year per consolidation. The first year average net gain for these 15 districts was $11,665 ($21,665 annual savings less $10,000 setup costs).

The seven remaining consolidation reports failed to reflect substantial cost or benefit data; however, qualitative benefits are assumed to be derived from these consolidations.

Because of lack of data, we must make the cautious assumption that this ratio of economic versus only qualitative returns also pertains to those consolidations which occurred before 1973. The total 161 district consolidations since 1968 consequently consist of 51 consolidations without economic return. Therefore, the economic gains are calculated only for 110 consolidations.

These 161 consolidations occurred at an accelerated rate from 1967 to 1971, then declined to the present; however, no data were provided on consolidations occurring after 1976. We presumed, therefore, that few, if any, consolidations have occurred since then. Nor is a distribution available for the implementations during the 1967 to 1976 period. To calculate the benefits, 1971 is assumed to be the weighted mean implementation year. (This assumption is, at most, 1 year off.) The study benefits are amortized over a highly conservative 4-year period. All costs and benefits are calculated at present worth for 1971. Further benefits for years 1972 to 1974 were discounted at 10 percent. Study costs from 1968 were accrued at 10 percent compound interest to 1971.

Amortization of economic net benefits derived from consolidations were:

Year 1 (1971)	
110 consolidations × $11,655/consolidation =	$1,282,050
Year 2 (1972)	
110 consolidations × $21,655/consolidation = (discounted to 1971 at 10 pct.)	2,165,500
Year 3 (1973)	
110 consolidations × $21,655/consolidation = (discounted to 1971 at 10 pct.)	1,968,636
Year 4 (1974)	
110 consolidations × $21,655/consolidation = (discounted to 1971 at 10 pct.)	1,789,669
Total savings discounted to 1971	$7,205,855
Rounded off	$7,206,000

Investment costs of the Size of Ranger District Study were:

Study team salaries (3 MaSS, 2 regional offices)	$116,000
Operating costs (travel, computer)	50,000
Steering committee (salaries, travel)	22,000
Field contributed time for interviews	10,000
Total	$198,000
Accrual for 3 years (1968 to 1971) at 10 pct. compound interest	$264,000

Appropriation Level Approximations

Savings resulting from the study or from not conducting the study could also be assumed to be returned to the U.S. Treasury through lower subsequent appropriations, rather than be reapportioned to other activities. In that case the benefits and investments must also include the relevant overhead charges at the level where the benefit or cost occurs and at all superior levels through which the funding is administered. The appropriation benefits and investment costs are calculated to be:

Benefits	
District management level	$7,206,000
General Administration and other management costs for Washington Office, Regional Office and Supervisor's Office levels (calculated at 31 pct. of net funding)	2,234,000
Total	$9,440,000
Investment	
MaSS level (approximately 42 pct. of total)	$111,000
General expenses (17.5 pct. at Station level, 3 pct. at Washington Office level) 20.5 pct. total	23,000
Subtotal	$134,000
Regional level (approximately 58 pct. of total investment)	$153,000
General expenses for Regional Office and Washington Office approximating 14 pct. of net funding	22,000
Subtotal	$175,000
Total	$309,000

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The return on investment of the Size of Ranger District Study was estimated to be:

Benefit cost ratios	
Reallocation basis	27.7
Appropriation basis	30.6
Internal rate of return on investment	184 pct.
Investment payoff period	
Average annual benefits	
Reallocation basis	$1,800,000/yr.
Appropriation basis	$2,360,000/yr.
Payoff period	
Reallocation basis	1.7 months
Appropriation basis	1.6 months

SOLID WASTE MANAGEMENT

Benefit-Cost Analysis

In 1970, the National Forests hosted more than 172 million recreation visitor-days, and spent more than $12 million to handle the solid wastes created by recreationists, about 96 percent of which were for collection and transport. An outcome of the Environmental Protection Act of 1969 was Executive Order 11507 which called for higher solid waste management standards. The introduction of higher standards meant disposal at centrally located sanitary landfills, which raised the cost for transport as well as for disposal. Therefore, more comprehensive methods to analyze solid waste systems were needed in order to keep disposal costs to a minimum. The Management Sciences Staff undertook the development of methods that could be employed by analysts at the National Forests. The development spanned a 2-year period—1971 to 1973. Our goal was the implementation of better plans for storing, collecting, transporting, and disposing of refuse.

The rural setting with its widely dispersed, small-volume waste-generating points sharply contrasts with the urban setting. Refuse is generated during short recreation seasons, lasting but 3 months in some places. Therefore, the collection schedule changes, often monthly. Compacting refuse is never done at the site of origin. Special wildlife-proof containers are sometimes used to keep the solid waste safe from wildlife. Trucks periodically transport refuse from collection to disposal sites. Collection cycles vary, depending on the attraction of the refuse to animals and its distraction to visitors. The preferred method of disposal is the sanitary landfill. None of the published, urban-oriented methods of designing crew routes are applicable to the rural situation; therefore, an entirely new approach was needed.

Study Approach

Other studies established a direct relationship between the amount of waste and the number of visitors for any geographical location. These findings permitted the Forest Service to estimate the amount of waste based on the number of visitors. The amounts of time required for collection were obtained from field studies, and depended on the truck size and number of crew members. The number of containers needed depended on the frequency of collection as well as campsite use.

The most difficult area was selecting routes. Each of the many alternatives required many calculations. To determine crew routes, the study team first fixed the landfill locations, crew sizes, collection frequency, and truck size. By using a different landfill location or truck or crew size, we were able to arrive at the best alternative based on a comparison of costs. When landfill sites can be operated less than daily, the bulldozer may be shuttled between landfills. We developed a simple break-even analysis that indicated when the cost of using one dozer is less than the cost of two bulldozers.

Since transport accounts for the major cost of solid waste systems, the basis of any design is the routing of crews.

We developed two methods of designing crew routes—a manual system and a computer-based system called SOWAD (Solid Waste Design), both widely used: SOWAD was used on forests with large numbers of waste generating points or large volumes of recreation use. All forests in the Rocky Mountain Region and selected forests in the Pacific Southwest and Southern Regions (N = 20) used the computer package. Approximately 15 other forests made partial use of the computer package. All other forests used the recommended manual procedures.

The methods that we developed may also be used for regional systems that embrace several agencies. Regional systems are often attractive because they offer economies of scale.

Benefits

Some adverse consequences would likely have occurred had this study not been undertaken, such as missing the implementation deadline, purchasing the wrong equipment, or choosing the wrong landfill location. However, such was not the case. Moreover, we also know that the published results of this study influenced at least a few other agencies including the Kentucky Department of Highways and the National Park Service, U.S. Department of Interior, as well as the Republic of Ireland.

The Texas National forests provide an example of how the method would facilitate better, cheaper operations. By making changes in truck capacities, landfill locations, and collection frequencies, we were able to develop 11

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different plans. The least expensive annual plan cost $19,200, the most expensive cost $29,400.

Standards set by Executive Order 11507 required a shift from local to centralized disposal sites, with a consequent increase in transport cost. In the opinion of the program coordinator in the Forest Service's Washington Office, the 1970 cost of $12 million would have increased in the subsequent years by about 50 percent to $18 million if the study findings had not been used. Although exact figures are not available, the actual annual cost from 1971 to 1973 is estimated at close to $15 million. But we do not credit the study with the full savings of $3 million per year. Instead we use a smaller figure that is derived in a different way.

On the basis of contacts with forest analysts, we concluded that the typical annual cost of the worst plan was about 50 percent more than the cheapest plan. We also concluded that without access to our published manual and computerized methods a plan would have been designed which, on the average, would have cost about 25 percent more than the least expensive plan. Put another way, the study helped achieve a 20 percent reduction in total annual costs on the 45 recreation-oriented forests that reflected the study's influence the most and which account for an estimated two thirds of the solid waste expenditures.

The total annual benefits by this computation are 20 percent of two thirds of the $3 million savings, or $0.4 million. This average cost reduction is then multiplied by the total years considered.

Implementing the waste management plan requires investments in equipment, training personnel, and sometimes agreements with local agencies. The solid waste disposal program originated in 1971 and was still mandatory in 1979. Some forests operate their program in-house, others contract it out. The transfer point scheme and routing patterns established by the study are generally still in use, but changes are expected. To calculate benefits only the 3-year period (1972 to 1974) is used, when the scheme was fairly rigidly followed. Therefore, the total savings for 3 years were $0.4 million per year, or $1.2 million (not counting savings in analytical effort).

Savings in Analytical Effort

An analyst from the Sierra National Forest worked full-time for 3 months to calculate alternative designs for one-half of the forest and indicated that another 3 months would have been required to complete the designs for the other half. Fortunately, SOWAD was used on the second half. The Sierra National Forest is typical of the 45 forests that used SOWAD; thus, the savings in analytical time can be estimated as one-half man-year per forest, or 22.5 man-years, to equal $450,000. This is a once-only savings. The analysis does not need to be repeated until conditions change significantly.

Estimated costs and related annual savings over a 3-year period, from 1972 to 1974, were:

Costs:	
MaSS study team salaries and expenses	$ 80,000
National Forest implementation costs	270,000
Total cost	$350,000
Savings:	
Operations	$400,000/yr for 3 yr
Analysis	450,000 one time in 1972 only
Total savings	$1,650,000

Investment Analysis

The investments were made primarily during 1971-72, and the benefits used in this analysis occurred during 1972-74. All costs are brought forward to 1974. All benefits and costs are discounted at a 10 percent interest rate as mandated by OMB circular A-94 (revised). In 1974 dollars, the accrued invested cost was $423,500. Investments occurred at the MaSS and forest level in the ratio of 1:2.9.

In 1971, MaSS was assessed only Pacific Southwest Forest and Range Experiment Station general expenses of 16 percent, to which must be added 3 percent Washington Office administrative costs. Added to the forest-incurred cost is 31 percent to arrive at joint appropriation level costs of $541,600.

The benefits were composed of the once-only savings in 1972 of $450,000, and $400,000/year for the period 1972 to 1974. When these savings are compounded and accrued, their 1974 present value is $1.87 million.

Since these benefits occurred entirely at the forest level, 31 percent administrative costs for Washington, regional, and forest supervisors' offices must be added to arrive at the appropriation level savings of $2.5 million.

Return on investment calculations for the Solid Waste Management Study are:

Benefit cost ratios:	
Reallocation basis	4.4
Appropriation basis	4.6
Internal rate of return on investment	34 pct.
Investment payoff period:	
Average annual benefits:	
Reallocation basis	$623,000
Appropriation basis	$833,000
Investment:	
Reallocation basis	$423,500
Appropriation basis	$541,600
Payoff period:	
Reallocation basis	8 months
Appropriation basis	8 months

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FOREST SERVICE TELECOMMUNICATIONS

Benefit-Cost Analysis

The Forest Service Telecommunications Study was begun in March 1970 and completed in November 1972. At the time of the study the Forest Service operated 22,000 pieces of radio communications equipment with an annual budget requirement of $6.3 million (not fully funded). An accumulation of problem areas necessitated new tools and recommendations for Forest Service telecommunications management, and new solutions to critical large-fire communication problems. The study recommendations and design specifications were accepted for implementation, subject to funding priorities in 1973. As of January 1979, nearly all recommendations had been or were being implemented.

The study required about 9 work-years of professional effort, 2 work-years of technician effort and 1 work-year of clerical effort.

Qualitative Benefits

Telecommunications Management

The impact of this study and its implementation on telecommunications management was dramatic. Before study implementation, budgets were inadequate, equipment was obsolescent, and planning was inadequate. This situation has changed. The new replacement policy has enabled regions to put budgeting on a firm basis, to integrate planning with established replacement cycles, and to satisfy communication requirements with the acquisition of new technology. Obsolescence costs have been greatly reduced or eliminated.

Large Fire Telecommunication

Based on experience up to this time, the critical large-fire communication problems have been resolved. The fire cache and air communications systems designed on the basis of this study have proven adequate to all demands, including the 1977 Hog fire in the Pacific Southwest Region involving five simultaneous major fires on two adjoining drainages.

Telecommunications Frequency Management

The replacement of obsolescent radio equipment allows greater flexibility in the use of the assigned electromagnetic frequencies.

Safety

The ability to communicate reliably and directly between the concerned parties improved greatly the safety of Forest Service firefighters and field workers.

Service to Public and Other Agencies

Study findings serve as a basis for negotiating with other agencies. The California Department of Forestry has joined the Forest Service's Pacific Southwest Region in the implementation of the new air operations telecommunications design.

Economic Consequences

Obsolescence

The major economic benefit from the study is due to the implementation of new technology. The shortening of the replacement cycle from an average 15 years to 11 years produced annual benefits of $480,000 in 1978 dollars. The benefits resulted from reduced power requirements, new power sources, reduced installation costs, increased portability, reduced breakdown and maintenance costs, and increased range and capacity of new telecommunications equipment. New technologies that are just now emerging—advances such as greater reduction in equipment size, smart repeaters and other microprocessor applications, duplexing and cavity applications, and solar power and satellite communications—assure continuing benefits from future modernizations.

Preventive Maintenance

The telecommunications study found that scheduled preventive maintenance could be eliminated without adverse effects on equipment reliability. The recommended elimination of periodically scheduled preventive maintenance reduced technician overload and forestalled increased staffing. In one region, the radio inventory increased by 78 percent since 1975, while the maintenance staff increased by 19 percent in the same period. Had preventive maintenance continued, an additional 1.5 work years per forest would have been required to accomplish this workload. Service-wide implementation of recommended replacement and maintenance policies was achieved in 1976. The elimination of the preventive maintenance program Service-wide saved 20 technician work years per year at an annual cost of $320,000 in 1978.

Large Fire and Air Telecommunications Systems

The new system is being implemented throughout the Forest Service and cooperating agencies. It has been fully operational in the Pacific Northwest and Pacific Southwest Regions since 1978. The new National Fire Radio Cache has also been operational since then. As yet no estimates of the economic benefits associated with the improved communications system are available.

Partial study benefits and study costs of the Forest Service Telecommunications Study were:

Estimate of economic benefits (1978 dollars):	
Reduced telecommunications systems cost due to modernization	$480,000/year[2]
Work force savings for the elimination of scheduled preventive maintenance	320,000/year[3]
Total $800,000 per year	

Study costs (1971 dollars)	
Steering committee	$ 25,000
Professional	180,000
Technical	20,000
Secretarial	7,000
Travel	27,000
Field participation	30,000
Total	$299,000
Study costs appreciated to 1978	$583,000

Return on Investment

The return on investment calculations are based on a 5-year life-span of report recommendations. The 5-year period extends from 1976 (when the two recommendations of accelerated replacement and estimation of scheduled preventive maintenance were implemented) to 1980. All costs and benefits are accrued or discounted to 1979. The discount interest rate used is the prescribed 10 percent. The 1971 study cost of $299,000 has an appreciated 1979 value of $641,000.

The monetary benefits over the 5-year period, 1976-1980, adjusted for 1979 present value amount to $4.48 million. This figure excludes the direct benefits from improved air and large fire communications.

The return on investment calculations follow two approaches. One approach is based on the reallocation of funds (saved funds are used on other projects) and the second approach is based on reduced appropriations. In the second approach, the direct costs and benefits are augmented by general overhead expenditures. In the present case, the direct benefits from telecommunications accrue at the field level and approximately 24 percent of appropriations are expended at higher administrative levels as overhead. The total field savings of $4.48 million is therefore augmented to $5.90 million to reflect savings of overhead expenditures. Investment costs had associated overhead expenditures of 19 percent of direct costs for expenditures incurred by the Management Sciences Staff and 3 percent for direct costs associated with other study participants. The study cost at the appropriation level is thus $339,000 in 1971 dollars and $727,000 when appreciated to 1979.

[2]Based on differences in prorated purchase and installation costs, costs of maintenance and cost of operations.

[3]Economic benefits associated with the resolution of the critical fire communication situation have not been evaluated but are at least equal to this total.

Based on these considerations, the return on investment in the Forest Service Telecommunications study was estimated as follows:

Benefit cost ratios:	
Reallocation basis	7.0
Appropriation basis	8.1
Internal rate of return on investment	46.8 pct.
Investment payoff period:	
Average annual benefits (1979 dollars):	
Reallocation basis	$0.9 million
Appropriation basis	$1.2 million
Payoff period (1979 dollars):	
Reallocation basis	8.5 months
Appropriation basis	7.5 months

COMPUTER SUPPORT SYSTEMS FOR MULTIFUNCTIONAL PLANNING

Benefit-Cost Analysis

The analysis of Computer Support Systems for Multifunctional Planning was begun in April 1973. The study consisted of three phases, each analyzing a specific area of support systems. Phase one, completed in January 1974, concerned resource planning systems; phase two, completed in July 1974, included additional resource planning systems and transportation planning systems; phase three, completed in June 1976, concerned resource information systems and mapping systems. The study objectives were to review the status and areas of applicability of multifunctional planning systems in use or under development, and to analyze the utility and organizational support requirement of each system.

The study required 6 work years of professional effort and about 1 work-year of combined managerial, clerical and technical effort.

Qualitative Benefits

Improved Systems Management

This study identified and analyzed the performance characteristics of 35 computer systems and subsystems, in relation to user needs, and provided operational cost comparisons for selected mapping systems based on benchmark data. It also identified systems which were not viable under the conditions of use prevailing at the time of the study and provided recommendations for further developments and improvements in the area of multifunctional planning systems.

Direct Service to the Public

Requests for the report were received from numerous universities and libraries; Federal, State and private land

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and water management agencies in the United States and Canada; as well as from private companies and individuals. We also received requests to use the report for teaching.

Economic Consequences

Prior to the study, duplicate or inappropriate systems development constituted a severe drain on Forest Service resources. The study identified areas of overlapping developments and the degree of perceived utility derived from systems in several areas of user applications. The study was thus instrumental in redirecting system development efforts to areas with high utility.

At present, the development of low utility and duplicate systems has nearly ceased and recommended improvements have been implemented. Not all of the benefits, however, are derived from this study. Although the computer support systems study developed early, a number of administrative actions occurred simultaneously with the release of the study. Specific economic benefits cannot be attributed, therefore, without a detailed analysis. The overall benefits of all of these studies and administrative actions were:

- Terminating inefficient systems and system developments, with an estimated benefit of about $2 million over a 3-year period
- Improving systems and systems utilization with an estimated benefit of $0.5 million over a 3-year period

Long-term benefits cannot be estimated. Indications are that they will be significant.

The cost of the study was $170,000.

ADVENT

Benefit-Cost Analysis

ADVENT permits multiyear, variable input-output analyses at the forest, regional, area, station and national levels. The major software components include an update program, matrix generator, and report writer. The alternative generation logic is based on linear programming. ADVENT is now being used for program development and budgeting at the forest, regional, and national levels and the RPA process. Additional applications are being developed in transportation and land-use planning, R&D project selection, and road maintenance budgeting. Among all analytical systems in Forest Service use in 1979, ADVENT appears to involve the most users, and to have had a most significant service-wide impact.

Benefits

Program Development and Budgeting (PD&B)

The first use of ADVENT for program development and budgeting was in fiscal year 1976 for the Eldorado National Forest. The next such application was in the same fiscal year for the Trinity National Forest but for sample data only. Region-wide PD&B analyses in the Forest Service were first performed during 1977 for the Pacific Northwest Region and in fiscal year 1979 for the Pacific Southwest Region.

Application of ADVENT to program development and budgeting rose dramatically in fiscal year 1980. Users include the Forest Service's Program Development and Budget Staff, in Washington, D.C.; all nine regional offices; and 54 National Forests in the Northern, Rocky Mountain, Intermountain, and Pacific Southwest Regions. An estimated 109 National Forests, with large budgets and a great mix of land resources, are expected to use ADVENT for fiscal year 1982.

Intangible Benefits

ADVENT is sufficiently standardized in terms of formats, software, reporting schemes, to allow completion of the planning without interruption because of constantly changing systems structure. But ADVENT is sufficiently flexible to allow for special program manipulations. It can also function independently of definitions, allowing such definitions to be changed when necessary.

Tangible Savings

DeClark and Monteith (1977) estimated the first-year installation and operations costs of ADVENT at $40,000 per National forest, and in subsequent years, $34,000. And—depending on the size of the forest—they estimated the costs of program development and budgeting for a National Forest not using ADVENT at between $50,000 and $80,000. The weighted average cost per forest is estimated at $60,000. Another source estimated that the cost of applying ADVENT to a National Forest averages $20,000, and that the cost of producing reasonably comprehensive program alternatives without ADVENT would average $75,000.[4]

If the more conservative figures from the study by DeClark and Monteith (1977) are used, the forest-level savings for the 54 forests using ADVENT in 1978 for program development and budget planning for Fiscal Year 1980 were:

$$54 \text{ forests} \times (\$60{,}000 - \$40{,}000) = \$1{,}080{,}000$$

Cost savings at the regional and national levels for the first year of use are not available. Line and staff esti-

[4]Personal communication from William G. Edwards, Program Development and Budget Staff, Forest Service, U.S. Department of Agriculture, Washington, D.C., June, 1978.

mates at these levels indicate that savings exceeded costs by a fair margin.

Three assumptions are made regarding the calculation of future benefits:

- ADVENT operating costs for the third and subsequent years do not exceed the estimated second year operating cost, and in all probability will be lower.
- The number of forests using ADVENT for program development and budget preparation will increase to a total of 80 for fiscal year 1981 and to 109 for fiscal year 1982, as planned.
- The life-cycle for a system like ADVENT is 5 years. Use of the ADVENT software for program development and budget planning will most likely extend beyond the 5-year range, but modifications and applications suggest a conservative time bound.

Estimated tangible 5-year life-cycle procedural savings from ADVENT for program development and budget applications are:

		Discounted to 1978
Forest level:		
Year 1	$ 1,080,000	$1,080,000
Year 2		
54 forests × ($60,000 - $34,000)		
26 forests × ($60,000 - $40,000)	1,924,000	1,749,000
Years 3 to 5		
3 years × 80 forests × $26,000/year		
2 years × 29 forests × $26,000/year		
1 year × 29 forests × $20,000/year	8,328,000	5,274,000
Total	$11,332,000	$8,103,000
Regional level:[5]		
5 years × 8 regions × $30,000/year /region	$ 1,200,000	992,000
National level:[5]		
5 years × $40,000/year	200,000	165,000
Total	$ 1,400,000	$1,157,000

Planners are beginning to use ADVENT to identify an optimal program from all the feasible projects at the forest level, and from alternative program packages at the regional and national level. An optimum program is defined as one which provides maximum resource outputs for a given budget, or a minimum budget for a given set of outputs.

Only the theoretical calculations have been made so far of the potentials of this growing use of ADVENT. They indicate an upper limit of possible future savings. Programs that are operationally and socially feasible have to be "suboptimal." Realistic savings will therefore be substantially less than the theoretical optimal savings.

[5]Data on procedural savings at the regional and national levels are not currently available. Estimated savings, however, are at least $30,000 per year per region and $40,000 per year at the national level, based on the estimated savings of $26,000 per year per forest.

Resources Planning Act (RPA)

The first program required by the Forest and Rangeland Renewable Resources Planning Act was developed, in 1975, without ADVENT. Consequently, the economic and alternative analyses were not as complete as they might have been. The second program required by the Act, announced in 1980, was developed with the aid of ADVENT. No other computer system was available or could have been developed for operational use by early 1978 when the planning process for the 1980 program was begun. The Forest Service's Program and Assessment Staff has indicated that without ADVENT, the agency could not have met the requirements for the 1980 program.

MaSS specifically modified ADVENT for use in developing the RPA program, allowing the Resources Program and Assessment Staff to make multi-objective analyses at the regional and national scales. ADVENT contributed substantially to the 1980 program by providing the technical capability to analyze, evaluate, and display alternative programs and their effects on the nation's renewable resources.

The Resources Program and Assessment Staff has estimated that without ADVENT a team of 30 people working 5 months (twice the 1975 team's effort) would have been needed to produce a potentially acceptable 1980 program without ADVENT. With ADVENT, only six analysts were required for approximately the same period. An additional $40,000 was spent on computer costs, but resulted in a far more precise, comprehensive, and reliable program. Thus, average savings for the 5-month period were

24 analysts (average GS-13 salary) for 5 months	$310,000
Computer costs	-40,000
Net savings at the national level	$270,000

Savings at the regional level are not available but can be expected to approximate the national level, or $250,000 net.

Development and Implementation Costs

The development cost for ADVENT is calculated to have been approximately $650,000 to $750,000. This includes contributions by all persons directly working on the development. Contributions by user participants, such as for implementation trials, are estimated to be approximately 1.5 times the direct cost. The total development and implementation cost, therefore, is approximately $2 million; accrued to 1978 at 10 percent, it is $2,420,000.

Direct procedural savings from the assumed 5-year life of the ADVENT system are shown below. The costs of implementing ADVENT for PD&B and RPA programming are included in the procedural savings (which have a high probability of achievement).

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	Basis		
	Reallocation		Appropriation
Program development and budgeting applications:			
Forest level	$11,332,000	[6]$8,103,000	
Regional level	1,200,000	992,000	
National level	200,000	165,000	
	$12,732,000	$9,260,000	$11,916,000
1980 RPA applications:			
National level	$ 270,000	$ 270,000	
Regional level	250,000	250,000	
	$ 520,000	$ 520,000	$ 563,000
Total	$13,252,000	$9,780,000	$12,479,000

Development Costs (Reallocation basis)	
$2,000,000 accrued to 1978 at 10 percent	$2,420,000
Development Costs (Appropriation basis)	$3,015,000

Appropriation Level Approximations

For these calculations the assumption is made that savings from the result of the study or from not conducting the study (i.e., study costs) are returned to the U.S. Treasury (lowered subsequent appropriations) rather than reapportioned to other demanding activities.

Benefits accrue at the national, regional and forest levels, but must be adjusted for General Administration and other management costs for appropriation level evaluations. The cumulative adjustment factors for the gross funding are 3 percent at the Washington Office level, 99 percent at the regional level, and 12 percent at the forest level; calculated for net funding, these cumulative adjustment figures are 3, 14, and 31 percent, respectively. The adjusted 5-year discounted procedural savings at the appropriation level is $12,479,000.

The estimated distribution (percentage) of the $2 million investment made in ADVENT, by level, was: national—10; regional—30; forest—35; MaSS—25. The development and testing of ADVENT reached its midpoint in 1976. The appropriation adjustment factor for MaSS for that year was 44 percent. The $2 million investment when adjusted to the appropriation level and accrued to a 1978 value is $3,015,000. Return on investment calculations for ADVENT are:

Benefit cost ratio	
Reallocation basis	4.0
Appropriation basis	4.1
Internal rate of return on investment	84.6 pct.
Investment payoff period	
Average annual benefits	
Reallocation basis	$1,956,000
Appropriation basis	$2,496,000
Investment	
Reallocation basis	$2,420,000
Appropriation basis	$3,015,000
Payoff period	
Reallocation basis	15 months
Appropriation basis	15 months

[6]Discounted to 1978 at 10 percent.

ROCK AGGREGATES TRANSPORT

Benefit-Cost Analysis

The mining, processing, and transport of rock—a nonrenewable resource—is of prime concern to land managers. The Forest Service, as well as other Federal, state, and local road-building agencies, is affected. An estimated $200 million annually is spent on the National Forests to produce and transport mineral rock for road construction and maintenance, and expenditures are expected to increase as high-grade sources are depleted. But the development of new sources may create a conflict because of competing land uses. Therefore, a mathematical model was used to analyze trade-offs between the environmental impacts and economic values of various proposals to develop aggregate sources for surfacing roads in National Forests.

The transport analysis helped resolve a conflict over the economics of competing land uses. For present purposes, only one application—using the Oroville and Quincy Districts of the Plumas National Forest in northern California—serves as the basis for estimating the benefits of this study.

In 1974, materials engineers warned that existing aggregate supplies in these two districts would soon be exhausted, and that the district rangers must permit either nearby new sources to be developed or be prepared to shift to existing, but distant sources. Both district rangers were hesitant about approving new development.

Thus, vital concern was raised over the adequacy of fewer sources, the cost of longer hauls, and the value of proposed sources. The problem is to match the sources of supply with the demands of the roads in such a way as to achieve the least total cost. Total cost included: developing or restoring quarry sites, processing the mineral rock, and transporting the aggregate to the roads.

We viewed the collection of mineral sources and the roads that required the materials as a "system." Using this notion, we agreed to generate alternative plans and compare each with the least expensive plan. In this way we could directly measure the cost of *not* developing a selected mineral resource, in other words its economic *worth*.

The district staffs would use expert opinion to weigh the physical magnitude of environmental disturbances, but they would use the model to weigh the cost of avoiding these disturbances by not developing mineral sources. They would also use the model for contingency planning—to determine which sources to acquire first and which to consider as substitutes if negotiations for the best sources should become stalled.

Each plan shows the amount hauled from each material source to each road segment during each time period. It also shows the timing of the opening and clos-

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ing of each source. Besides satisfying the material requirements of each road, the model includes a limitation on productive capacity of each material source for each period.

The mathematical formulation of this problem comprises more than 700 equations and almost 1,200 algebraic variables (Kirby and Lowe 1975). The solution uses a mixed integer programming algorithm (computer program).

Benefits

The initial plan assessed the cost of all potential aggregate resources. The costs were then compared to the expense of alternative plans. The alternative plans were higher in cost because reductions in production and development could not offset the high cost of transporting aggregate from a distant source. The cost difference then is a direct measure of the dollar worth of the deleted source.

We ranked the mineral sources according to their dollar worth. The initial case with all sources available required out-of-pocket costs of over $9 million for the 20-year period, corresponding to a net present worth of $5.17 million (10 percent discount rate). Eliminating the first ranked source, the most worthy, raised the cost by $1.33 million. Eliminating both the next two ranked sources raised the cost almost as much, by $1.1 million. Since the sources are so valuable the districts could afford to spend rather large sums to make them esthetically pleasing and to avoid other adverse environmental impacts.

Without this study, the responsible engineer at the Plumas National Forest would have devised a less than optimal plan because the required combinations could not be found by conventional methods of solution. The engineer calculated that the study will save the government $55,000 per year over an expected 20-year utilization period at the Plumas National Forest.

It was estimated that the model could be profitably applied on the 13 to 20 National Forests with the largest timber workloads, and that the resulting cost savings would total $1 million per year for at least 5 years, or approximately $50,000 per forest per year.[7] Also included is a one-time investment cost of $130,000. According to several forest engineers, most expenditures labeled timber purchaser credits were allocable to the manufacture and placement of rock aggregates for roads. If so, this would amount to $200 million per year for the Forest Service. Thus, a potential cost saving of $1 million per year would be very conservative.

Because of the uncertainty of predictions and the likelihood of a solution by others, benefit calculations are based on a 5-year life span of this methodology.

[7]Personal communication from J. Mandigo, Engineering Staff, Forest Service, U.S. Department of Agriculture, Washington, D.C.

The district rangers at the Plumas National Forest are utilizing the study as the basis for creating a minerals management policy and to negotiate with private owners for the acquisition of desirable mineral sources. Two other district rangers at the Plumas and Siuslaw National Forests plan to use the model as a basis for cost-sharing agreements between agencies where one agency supplies material to another. The approach is also applicable to other materials, such as logging slash, that are transported to central disposal sites.

Thus far, the only reliable data has come from Plumas National Forest, with reported savings of $55,000 per year (1977 dollars). The methodology is expected to remain in use for at least 5 years. The identified 5-year benefits (1977-1981) adjusted for inflationary increases and discounted to 1977 are $279,000 at the reallocation level.

To adjust the benefits to the appropriation level, general expenses of 31 percent are added, bringing total benefits to $365,500.

Investment

The study team was composed of a senior MaSS operations research analyst, one engineer from the Plumas National Forest, and two engineering analysts from Pacific Southwest Region. All participants were part-time. The design, test, and implementation was therefore possible with small manpower investment. The costs (1977 dollars) were calculated as follows:

Study team salaries	$19,500
Travel and computer	$ 2,500
Total (reallocation basis)	$22,000

To obtain the costs at the appropriation level, general expenses for the Forest Service's Washington Office, regional office, supervisor's office, and Pacific Southwest Forest and Range Experiment Station were added. The total investment cost at the appropriation level came to $28,200.

Return on Investment

Return on investment calculations for the Rock Aggregates Transport Analysis are:

Benefit/cost ratio	
Reallocation basis	12.5
Appropriation basis	13
Internal rate of return on investment	163 pct.
Payoff period	
Average annual benefits	
Reallocation basis	$55,800
Appropriation basis	$73,100
Payoff period (years)	
Reallocation basis	5 months
Appropriation basis	5 months

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These calculations assume that the investment is amortized solely through the benefits derived at the Plumas National Forest. The anticipated wider application would naturally increase the return ratios by a factor equal to the number of participating forests.

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In 1962, the Management Sciences Staff was organized in Berkeley, Calif., as the internal consultant to the Forest Service, U.S. Department of Agriculture. From then until 1979, the Staff conducted 41 major studies. Although the rate of implementing recommendations from these studies was high, a more formal self-assessment was considered advisable. The following six case studies with the largest investment were analyzed: size of Ranger Districts, solid waste management, radio telecommunications design and management, computer support systems, ADVENT, and rock aggregates transport. The results suggest that all six studies have proved to be good management investments.

Retrieval Terms: cost/benefit analysis, investment analysis, engineering economics, Management Sciences studies, return on investment, research evaluation